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TABLE OF CONTENTS.

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THE AMERICAN

METEOROLOGICAL JOURNAL.

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ORIGINAL ARTICLES.

MOUNTAIN METEOROLOGY.*

The euphonious title of "Mountain Meteorology," given to these lectures, is intended to indicate the meteorological phenomena of the upper air however observed.

It is generally admitted that one of the greatest drawbacks to a full understanding of meteorological phenomena lies in the fact that the observations on which we base our knowledge are generally made close to the ground and therefore in the most restricted air stratum. We indeed stop on the very threshold in our investigation.

When one looks from a high mountain-peak out into the open ocean of air and sees the clouds float far above, and then looks down on the plain and valleys where, from our standpoint, even hills have sunk to gentle undulations and high buildings disappear altogether, one is tempted to despise the poor means with which we are trying to study the ever-changing conditions of the aerial ocean. Down below where the air, murky and heavy with smoke and dust, stagnates on the ground, where shallow fog-banks hang over the valleys and along the rivers, there we have placed our instruments to measure the flow as well as the thermal and hygrometric condition of the whole atmospheric mass. It is not strange that we have often been unable to find the clue to the cause of the atmospheric phenomena, but, on the contrary, we may be surprised that we have succeeded so well.

* Extracts from a series of three lectures delivered before the Lowell Institute of Boston in 1891, by A. LAWRENCE ROTCH.

True, meteorological instruments have been taken in balloons high into the upper air in order to determine the conditions prevailing there, and if the atmosphere were only in complete equilibrium, then such irregular observations, as regards time and place, would give some data upon which to base general laws; but in the actual condition of continual movements and changes in the atmosphere, this can never suffice. Observations in captive balloons alone promise better results, for the lower air, up to a height of a few hundred yards. But what is impossible in a captive balloon, the maintenance of regular and continuous observation of all the meteorological elements, at all seasons and in in all weather, can only be done on mountains. When the earth's surface rises in plateaux, the advantage of the elevation above the sea, that is to say the immersion in the upper strata, is almost entirely neutralized, by placing our instruments in air masses which are affected by contact with the earth. For this reason meteorological observatories should be located on high and isolated peaks.

It will be seen that, while on the one hand the general atmospheric movements, both in velocity and direction, are much modified in the lower strata, on the other hand the aerial envelope differs greatly both in temperature and humidity from the free air, so that conclusions can only be made with respect to the relation of the former to the latter. It becomes evident that the more strongly agitated upper-air strata react on the lower in many ways, and that the knowledge of the movement of the high atmospheric layers is not only of great importance for the theory of the general atmospheric circulation and for a knowledge of the connection of meteorological phenomena, but also that it can aid much towards attaining the long-sought-for goal of trustworthy weather predictions. In this way observations on mountains complete those of the usual low-level stations. Were it not for the fact that mountains are not evenly distributed over the earth's surface we should be able, by erecting a relatively small number of well-distributed mountain stations, to realize great progress in theoretical as well as practical meteorology.

But with the existing topography, there are numerous well-situated peaks and the few stations which have already been built upon them have given such important results as to indicate the necessity of pursuing this method of investigation. The erection of mountain observatories and the discussion of their

observations are certainly steps in the rapid progress of meteorology during the last ten years, by which it has reached a high place among the other sciences.

I shall now describe the general features of mountain climate. By *climate* we understand the meteorological conditions characterizing the general atmospheric phenomena at any place which are the sum of the transient phenomena which we call *weather*. A study of climate must also include the probable and possible deviation of the extreme from the average conditions. Though in one sense climatology is only a branch of meteorology, it pre-supposes a knowlege of the most important doctrines of meteorology, as the latter does of climatic principles. If only one of these subjects is to be considered, therefore, it must be left to the author how much knowledge of the other shall be tacitly assumed.

Mountain climate has in all latitudes one peculiarity which distinguishes it from that of the neighboring lowlands, or, in other words, mountains modify every climate in a certain way, so that all mountainous climates possess certain characteristics. Together with the distribution of land and water, the elevation of the ground above sea level is the most potent factor which causes the variety of climate in the same latitude. For this reason it is important to get a general view of each phenomenon which is common to a gradual ascent from a low to a high level and to ascertain its cause.

In considering these phenomena I have mainly followed the order and theories adopted by Hann in his *Klimatologie*, modifying them occasionally in the light of more recent developments. It is to Dr. Hann that we must look for our best knowledge of mountain meteorology, and though some of his early opinions have changed with the discussion of new data, I believe that they are well substantiated.

The meteorological phenomena which are common to all mountain climates are as follows:

The diminution of atmospheric pressure with altitude is the most regular of the current meteorological phenomena, so that the pressure at any height, if the mean air temperature is known, can be calculated with quite sufficient accuracy for climatological purposes. Table I. gives for differences of elevation the corresponding atmospheric pressure, assuming that the pressure at sea level is 762 mm. (30 inches) and that the temperature decreases uniformly 0.5° C. for each 100 m., or about

1° F. for 300 feet rise. From the table it is seen that at the same height in the tropics and in colder climates, the mean pressure is not the same. At a height of 3,000 meters with a surface isotherm of 0° C. the pressure in winter amounts to 517 mm. and in summer with an isotherm of 20° it increases to 532 mm., which are about the conditions prevailing over Central Europe. The column, "Change of Pressure for 1°C," shows what effect a change of 10 in the mean temperature of the air-column has on the barometer. The last column on the right shows how high one must rise to make the barometer sink 1 mm.

TABLE I.

DECREASE OF PRESSURE WITH ALTITUDE.

(HANN).

Altitude in Meters.	Temperature at Sea-level in C°. Mean Pressure in Millimeters. 0°	5°	10°	15°	20°	25°	Change of pressure for 1°C.	Change of Height for 1 mm. difference of pressure.
0	762	762	762	762	762	762	0.00	10.5
500	716	716	717	718	719	720	0.16	11.1
1000	671	673	675	676	678	679	0.32	11.8
1500	630	632	634	636	639	641	0.44	12.5
2000	590	593	596	599	601	604	0.56	13.4
2500	553	556	559	563	566	569	0.67	14.2
3000	517	521	525	529	532	536	0.76	15.1
3500	484	488	492	497	501	505	0.84	16.1
4000	452	457	461	466	470	475	0.91	17.2
5000	394	399	404	410	415	420	1.02	19.6
6000	343	348	353	359	364	370	1.09	22.5

The chief characteristic of the pressure at high altitudes in temperate or northern regions is a higher pressure in summer and a lower pressure in winter, which is a consequence of the action of the temperature on the atmospheric strata, and the general reason for both annual and diurnal changes lies in the fact that when the atmosphere is contracted by cold so as to cause an inflow of upper currents, there will be, nevertheless, a relatively low pressure at great altitudes because so much of the air is condensed in the lower strata; on the other hand, when the atmosphere is warmed and expanded causing an outflow of upper currents and a relatively low pressure at sea-level, there will be a relatively high pressure at elevated stations because

so much air is lifted above them. Thus the barometer varies inversely at high and low levels.

The variation of pressure which the human organism can withstand is extraordinary. Among the highest inhabited places are the Pike's Peak Signal Station in Colorado, at a height of over 14,000 feet, where the mean pressure is $17\frac{3}{4}$ inches and the mean temperature 19° F.; the village of San Vincente in the Bolivian Andes at a height of 15,000 feet, and the Convent of Hanlé in Thibet, still a little higher, with a barometric pressure of 17 inches and an air temperature of 35°.

In mountain ascents in the Himalayas a height of over 22,000 feet with an atmospheric pressure of $13\frac{1}{3}$ inches has been reached, and Glaisher ascended in a balloon 29,000, feet where the temperature was minus 5° and the pressure $9\frac{3}{4}$ inches, or only one-third of the normal pressure at sea-level.

The so-called mountain sickness which manifests itself in headache, shortness of breath, exhaustion, etc., makes itself felt at various heights according to individual constitution, but it can often be overcome by acclimatization. According to Paul Bert, the influence of diminished pressure remains unnoticed until the pressure of the oxygen is diminished one-fourth, corresponding to an altitude of about 6,600 feet. Then the decreased pressure shows itself by a slight condensation of the oxygen in the blood and the cause of the physical weakness of dwellers at great heights lies in the insufficient oxidation of the blood in the varied air.

With the elevation above the sea, absorption diminishes or, inversely, solar radiation increases. Since, also, the aqueous vapor absorbs more rays than the dry air, and decreases with elevation more rapidly than the pressure, as seen in Table II. the intensity of the insolation augments faster than one would conclude from the pressure alone. Thus in the Himalayas a black bulb thermometer *in vacuo* has registered 25° above the boiling point of water while the shade temperature was only 75°. Violle found that the intensity of the solar radiation on the top of Mont Blanc was 15 per cent. greater than on the Glacier des Bossons, nearly 12,000 feet lower, and was 28 per cent. more than at Paris. That the humidity of the atmosphere has great influence upon the absorption, and especially upon the less refracted rays of the solar spectrum, from yellow to red, was proved by Prof. Langley upon Mount Whitney, at a height of 14,500 feet, in the incomparably dry air of California.

An intense insolation on clear days is an important characteristic of mountain climate, which is not properly judged with respect to its vegetable, and partly also, with respect to its animal life, if the thermal conditions of the air alone are considered. By high soil temperatures and great intensity of light the mountain climate differs from that of the polar regions having the same air temperature. For example, on the summit of the Faulhorn in a small space are 131 flowering plants, while in all Spitzbergen there are but 93. There the long day cannot replace the lesser solar intensity, the ground does not rise above the air temperature, and the earth remains frozen at a depth of several inches. The rarefaction of the air and the decrease of the contained water vapor with height gives, with the intense insolation during the day, a great radiation of heat at night. Thus on Mont Blanc the temperature of the snow has fallen 35° below freezing while that of the air was only 11° below.

The decrease of temperature with height corresponds to the increase of insolation. De Saussure, in 1788, made the first measurements of this in the Alps and found an average decrease of 1° F. for each 291 feet of ascent. From later observations, embracing the whole year and disregarding local influences, it can be stated that the decrease of temperature with height from the equator to about 60° north latitude is constant, and averages 1° for 316 feet. But local conditions are very important. For example, the decrease is much more rapid on the south than on the north side of a mountain, and in those countries where there is a winter, and especially a snow covering, there is a marked annual period in the decrease of temperature with height. Thus in Europe and the United States the decrease in summer is half again as rapid as in winter.

From recent observations on the Sonnblick and at lower stations Hann has found that up to 3,000 or 4,000 feet above the earth's surface the decrease of temperature is very variable. In cold, clear weather it was generally colder at night at the earth's surface than at a height of 1,000 or 2,000 feet. Above this the decrease was nearly constant for all altitudes, but varied with the season and time of day being slowest with the lowest temperature, and *vice versa.* It is to be noted that in Glaisher's balloon ascents up to 29,000 feet, on the contrary, the decrease was found to become slower as he receded from the earth.

On clear nights, especially in winter, during calm weather, it is frequently observed that the valleys are colder than the

slopes and crests of the surrounding mountains. The cause of this may be attributed to nocturnal radiation by which the arrangement of the thermal layers, according to their specific gravity, is aided by the calm air. This climatic amelioration is utilized in the cultivation of delicate trees, etc., and dwellings on slopes or hill-tops have not only the advantage of less humidity but also of a much milder nocturnal temperature. For this reason in the Alps one sees many little villages, situated not in the more convenient valleys but on the heights, often far distant from the pastures belonging to them.

During the clear, calm weather which accompanies a high barometer, slowly descending currents of cold air fill the valleys like rivers, while the summits receive the air warmed dynamically by descending from a greater height. So it often happens that for a long time in winter an extraordinary warmth prevails on the mountains, while in the valleys there is severe frost. At the same time, while the low lands are covered with fog, the result of the cooling of the lower air and the consequent condensation of the condensed vapor, the upper air is very dry. During a barometric maximum over the Alpine region the mean temperature in the valley was 20° colder than a mile higher, and under the same condition the temperature on Mount Washington in December, 1884, was from 30° to 40° above that near its base.

In windy, stormy weather, the temperature decrease with elevation is the most rapid because it approaches most nearly that of the ascending air currents. The low temperatures on a high mountain cannot be measured by the thermometer alone, but are also physiological, so that they are not comparable with the low temperatures of the plains and valleys which occur in calm weather as the result of radiation instead of during high winds, which increase greatly the physiological effect of the cold. This has been noted on the Sonnblick in Austria, on Mount Washington, in this country, and elsewhere.

In general, the annual range of temperature diminishes with height so that at an elevation of about 39,000 feet, which is the height of the cirrus clouds, probably the temperature is constant throughout the year. Mountain climate bears an analogy to littoral climate in the retardation of the time of lowest temperature, which, on high mountains, does not occur until February, or even March, so that it is in the early spring that the difference of temperature between the mountain heights and

the country below is greatest. While below the snow has disappeared and the ground is strongly heated, at great altitudes the whole energy of solar radiation is expended in melting the snow.

TABLE II.

RELATIVE DECREASE OF AQUEOUS VAPOR AND AIR PRESSURE WITH ALTITUDE.

(HANN).

Altitude in Meters.	Aqueous Vapor.	Air.	Altitude in Meters.	Aqueous Vapor.	Air.
0	1.00	1.00	5000	0.17	0.54
1000	0.73	0.88	6000	0.12	0.47
2000	0.49	0.78	7000	0.08	0.42
3000	0.35	0.69	8000	0.06	0.37
4000	0.24	0.61	9000	0.04	0.32

The decrease of the aqueous vapor in the atmosphere with heights takes place much faster than the decrease of pressure. Table II. gives the relative amount of vapor in the air at various heights, that at the earth's surface being called unity, and in the same way, for comparison, the relative atmospheric pressure. When in summer the vapor tension at the earth's surface is 10 mm., in the same latitude at a height of 4,000 m. it is only 2.5 mm.; at the equator a vapor tension of 20 mm. corresponds to 4.8 mm. at the above elevation, the air pressure being in both cases about 470 mm. At an elevation of about 2,000 m. half the quantity of aqueous vapor is below, while the atmospheric pressure only becomes half that at the earth's surface between 5,000 and 6,000 m. above it.

In this respect mountains have an important influence on the vapor envelope about the earth, since high ranges may separate very moist from very dry air. The relative humidity, or the degree of saturation of the air with aqueous vapor at great heights is the inverse of that at low-levels, that is to say, in winter there is great dryness and in summer great dampness, while in the lower regions the greatest relative humidity occurs in winter and the least in summer.

The peculiarity of the hygrometric conditions at great altitudes is the rapid change from complete saturation to extreme dryness. These alternations are frequent on isolated peaks and are accompanied by analagous thermal changes. Ascending air currents bring aqueous vapor from below, which rapidly becomes cloud, while descending currents carry down the dryness of the

upper strata. On the Grand Plateau of Mont Blanc, Martin found the relative humidity during three days to be thirty-eight per cent. with a minimum of 13 per cent., while at Chamonix during the same time the average was 82 per cent. and the lowest 50 per cent.

Another effect of extreme atmospheric dryness is the great transparency of the air. On the plateau of Thibet, all sense of distance is lost and one sees as through a vacuum. On Mount Whitney Prof. Langley remarked the same thing and noted also the purity of the sky, which appeared of a deep violet color.

The cloudiness varies with height irregularly according to the locality. In high latitudes, especially in the Alps, winter is the clearest season, while spring and summer are the most cloudy, that is to say, the annual period is the opposite of that at low-levels, and the autumn and especially clear winter is one of the most characteristic features of the high Alps, since in connection with the rarefied air it causes a very intense insolation.

Mountains have the greatest effect upon the frequency and quantity of the precipitation which is the result of the cooling of the rising currents along their flanks and the consequent condensation of the contained moisture. Most mountain ranges have a wet and a dry side. The former is that which is directed to the prevailing rainy wind of the region, such, for example, as comes from the sea or from a lower latitude. Mountains, such as the Alps, whose axis runs more nearly parallel to these winds have no pronounced wet and dry sides.

Apart from local conditions, the rainfall increases up to a certain height, after which the quantity diminishes again. Still, in general, if a chart be drawn with lines of equal rainfall these isohyetal lines, as they are called, will follow nearly the contours representing equal elevations.

The quantity of precipitation and the mean insolation are the two most important factors on which the lower limit of the snow on mountains depends. Its mean air temperature varies from 3° to 12° and it is evident that the snow-line is found with the lowest mean temperatures when the extremes from winter to summer are greatest, and the snowfall is small. Conversely, the snow-line is in a temperature above freezing when the annual range of temperature is small and snowfall is abundant. The elevation above the sea and the mean temperature at which

the inferior limits of glaciers are found depends still more upon local conditions.

Mountain ranges produce certain air currents and also modify the currents already existing. In the first category the most important and interesting are the day and night winds. In all mountainous regions where there is no prevailing wind there is a wind blowing into the valleys during the day and out from the valleys during the night. The regularity and force of these winds depends upon the topography of the country and the thermal relations. The theory of these alternating day and night winds, which have much analogy with the land and sea breezes on the coast is this: The cool night wind is caused by the sinking of the cold air into the bottom lands and it is most intense in narrow valleys where there is a great difference between the temperature of the valley and the plain. During the day the mountains act on the neighboring air like a stationary barometric depression, causing a rising current along the flanks of the mountain and a nearly horizontal flow of air up the valley towards the mountain.

At night the descending air currents, unlike the day winds, bring the moisture below, the clouds are dissolved and the air becomes very dry, as De Saussure was astonished to observe on the Col du Géant. The view from mountains is clearest in the morning because the humidity remains in the valleys and the air is quiet. In the afternoon, on the contrary, the atmosphere becomes thick and even cloudy from the uprush of warm air, while haze obscures the distance.

Mountain winds have local names according to the localities in which they occur. The best known is that first observed in North Switzerland, where the southwest wind, modified by the Alpine chain, is called Föhn. The Föhn is a violent, warm and dry wind from the enervating effects of which men and animals suffer and which favors conflagrations in the villages. The temperature, even in winter, becomes summer-like and the relative humidity diminishes greatly. The former rises sometimes 60° F. above the normal, while the relative humidity sinks as many per cent. In the spring, enormous quantities of ice and snow are suddenly melted, amounting in one case to over two feet in twelve hours, or more than the sun would melt in two weeks. There has been much discussion concerning the origin of the Föhn, but it has been shown by Dr. Hann that it owes its extreme warmth, as well as its dryness, to the descent from the

ridges on the north side of the Alps, and that it does not bring them from further south. The warmth of the Föhn is explained by the fact that a mass of air sinking into one of higher pressure is warmed at the rate of 1° for each 300 feet of descent, and a rapidly sinking stream of air which is so quickly heated must be relatively very dry.

The Föhn has been shown to exist in Greenland and New Zealand, while the Chinook, prevailing along the eastern slopes of the Rocky Mountains, is a strong, westerly wind having the same characteristics. Loomis showed that in the case of a storm passing over the Rocky Mountains, the vapor contained in the air would mostly fall on the west side, so that the air would descend on the east side deprived of its moisture and with a temperature above that which prevailed in the Salt Lake basin, on account of the latent heat liberated by the condensation of the vapor. In this way a change of temperature at a single station of 50° may occur in an hour, and at Denver a fall of 36° was recorded in five minutes consequent upon a change of wind direction.

The modifications in the general winds at high altitudes, which being nearly independent of the mountains can best be observed on them, are very marked. These winds have a much higher average velocity, not only on account of the absence of friction with the ground, whereby the movement of the lower air is greatly retarded, but also on account of the increased barometric gradients in the upper air. According to Davis, these winds are steadier than the lower winds, for the causes producing seasonal, diurnal and cyclonic variations, have their seat of action in the lower two miles of air. Above this the upper winds are generally westerly, except close to the equator, forming the general planetary circulation which results from the difference of temperature between the equator and poles and the deflective action of the earth's rotation. The diurnal change of the velocity and direction of the upper wind as compared with that at the earth's surface, which is one of the most interesting results of theory confirmed by observations obtained from the mountain stations, will be considered in my last lecture.

With the very imperfect review of the climatic conditions known to prevail in the upper atmosphere, we are better prepared to understand the special subjects which remain to be investigated. For the purpose of formulating them the per-

manent committee of the International Meteorological Congress, which met at Vienna in 1873, requested Dr. Hann to draw up a report on the question: What observations have been made on high mountains and in balloon ascents, and what methods are to be followed to achieve the best results? The report which was presented to the International Congress of Rome in 1873 was in three parts: The first gave a summary of the existing series of observations, the second stated what meteorological problems could be solved by observations on high mountains and the precautions which should be taken to secure the best results and upon them, forming the third part, were based the propositions to be ratified by the Congress.

In accordance with the recommendation of Dr. Hann the Roman Congress in 1879 adopted, among other resolutions, the following:

(1) The Congress recognizes the importance which balloon observations, especially in plains situated in the interior of continents, would have for the physical investigation of the atmosphere at great heights. It especially recommends, following the example of Glaisher, the determination by means of a captive balloon of the temperature and humidity of successive strata on different days and at different seasons. The Congress recommends, likewise, the investigation, by means of a captive balloon, of the daily march of temperature and humidity at considerable elevations above the earth's surface.

(2) The Congress thinks that it would be very useful if observatories could possibly be established on the summits of mountains, and the observations published *in extenso*, so that they may be placed at the disposal of all meteorologists and may aid in the solution of problems which may present themselves in future.

The Congress insists upon the utility of a series of hourly observations of temperature, pressure, direction and force of wind and eventually, also, of humidity, on Mount Washington, and especially on Pike's Peak, the highest station upon the earth. This series should embrace one year at least; and it would also be desirable to publish in detail the observations already existing for these two stations.

The Congress considers that the installation of a high summit station in Switzerland is especially desirable, and expresses the hope that meteorological stations may be established under similar conditions in Italy and in other countries.

Dr. Hann enumerates in his report the summit stations actually in operation, from which it appears that there were but three in Europe (Schafberg, Obir, and Puy de Dôme) and two in America (Pike's Peak, and Mt. Washington). Since 1879 there has been a great increase in the number, except in the United States. Nearly all the stations have been visited by me since 1885, and a description of the European stations will be found in this JOURNAL, Vols. II, III and V. I have confined myself almost entirely to stations situated on or near the summits of mountains, as for the reasons already stated, observations made on mountain sides, in passes or on plateaux are of much less value. Although meteorological observations upon mountain summits have been carried on for short intervals in various parts of the world, permanent summit stations exist, to my knowledge, only in Europe and on the American continent. For this reason the stations situated on the high plateaux of India are not considered.

In comparing the work done by the various nations in carrying out the resolutions of the Roman Congress to advance mountain meteorology, France certainly stands unrivaled in her superb chain of mountain observatories on the Pic du Midi, the Puy de Dôme, the Mount Ventoux and the Aigoual—the last still unfinished—whose construction has cost hundreds of thousands of dollars and years of time. They are generally defective in having no coöperating base stations, while the observations have not been published in detail. The services already rendered to meteorology by the Eiffel Tower should be mentioned.

The German and Austrian stations which are frequently ill-adapted to the purpose, being located in inns below the summits, have had their records published in more detail. The Sonnblick and the Hoch Obir in Austria may be mentioned as having been very prolific of results under Dr. Hann's management. Some of the stations have been much aided by the Alpine Clubs.

Switzerland, which since 1863, had maintained high stations in Alpine passes, etc., and published the observations, has recently established a fine summit station on the Säntis from whose records important deductions have been drawn by Director Billwiller.

Italy possesses several high pass stations and costly observatories on Mount Cimone and on Mount Etna have long been in

process of construction. The observatory on Vesuvius is chiefly for electrical and seismological research.

Great Britain, which for years took no interest in high-level meteorology, has now one of the most remarkable stations on Ben Nevis, the highest mountain in the British Isles, where for six years an unbroken series of hourly observations has been maintained. There is a base-station at sea-level and the advantageous situation of both render the publication of the full observations with their discussion by Dr. Buchan of great interest.

Coming back to the United States, which has the oldest mountain summit station in the world on Mount Washington, and for years maintained the highest on Pike's Peak, it is the more to be regretted that these observations have not been published in detail year by year by the Signal Service and so rendered generally useful for study. Suitable base-stations with which to compare the observations have also been lacking, as well as self-recording instruments generally.

The expedition of Prof. Langley to Mount Whitney for physical research was notable for meteorology in consequence of a determination of the solar radiation and absorption, upon which depend all atmospheric movements.

Prof. Pickering, the director of the Harvard College Observatory, may be considered the greatest benefactor to mountain meteorology in this country. With a view mainly of determining the best conditions for a high-level astronomical observatory, he has maintained temporarily several mountain stations and has lately had in operation in the Peruvian Andes a series of stations provided partly with registering instruments, one of them, Vincocaya, being perhaps the highest in the world. Besides this, Prof. Pickering has published the complete Signal Service observations on Pike's Peak and is aiding in the publication of the Blue Hill observations.

With respect to the use of balloons for meteorological purposes, as advised by the Congress, virtually nothing has been done since the ascents of Glaisher in 1862–6. Of late the Germans, in connection with military ballooning, have attempted meteorological observations with improved instruments for the determination of temperature and humidity. Some of the difficulties attending observations in free balloons will be shown in my last lecture.

[TO BE CONTINUED.]

ON THE VARIOUS KINDS OF GRADIENTS.

BY LÉON TEISSERENC DE BORT.*

The necessity of expressing accurately the rapidity with which the pressure varies when one moves in a plane in a given direction has given rise in meteorology to the idea of gradient which designates the variation of pressure per unit of length measured normally to the isobars. The unit of length originally chosen was the terrestrial degree, but for the accuracy demanded by the progress of meteorology the gradient over a shorter distance is often necessary and the kilometer or mile is taken for a unit of length. Finally, in the mechanics of the atmosphere the gradient can be represented by the relation $\frac{\partial p}{\partial k}$ (p being the pressure and k the distance normal to the isobars) and in this case the horizontal gradient is nothing more than the tangent of the angle formed by the surfaces of equal pressure and the surfaces of static level.

The air is put in motion by the differences of pressure and there ought evidently to be a relation between the gradient and the wind velocity. This relation has been made the subject of statistical researches, particularly in England and America, but although the wind increases with the gradient, there is no exact ratio nor a constant relation from day to day.

In these investigations, the fact has not been considered that theoretically the acceleration imparted to the wind is alone proportional to the gradient and not to the velocity; in using means it can be admitted that up to a certain point the velocity is proportional to the gradient since certain winds are commencing their movements and others, on the contrary, have been acted upon for some time by the differences of pressure, so that there results on the average a partial compensation. But this is only approximate.

It is evident, however, that friction being constant in the same locality from day to day, and being connected with the velocity by laws, little known but invariable, the continual anomalies which are observed in the wind's force for a given gradient tend to prove that equal gradients do not produce equal accelerations because their effects are not the same.

We will examine why this is. Let us analyze first the origin

* Translated from the *Memoires du Congres meteorologique de* 1889.

of the differences of pressure; and let us take the simple case where equal temperatures at A and B (Fig. 1) decrease equally and when there is no movement of the air for other causes, then are these surfaces of equal pressure parallel to the earth's surface, and $AA' = BB'$.

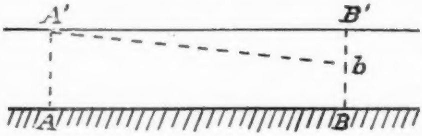


Fig. 1.

If we now lower the temperature towards B, the air will contract and the surfaces of equal pressure will incline, then there will no longer be equilibrium from A' to B'. and the air at this altitude will have a motion which, if there was no friction, would be represented by the formula $V = \sqrt{2\,gh}$, (h being the distance $B'b$ by which the surfaces differ from the horizontal plane).

The difference of pressure corresponding to this height h, divided by the distance AB will give us the gradient. It is seen, in this case that the difference of pressure is completely employed in putting the air in motion and in overcoming the friction. This is essentially a *motor gradient*, and as this gradient is the origin of all general movements we will call it *motor gradient of the first order.*

The movement of the air from A' to B' persisting, by reason of the excess of the temperature of AA' over BB', a part of the air which was above A flows towards b, the pressure augmenting at B and propagating itself towards the neighboring points, there will arrive a movement where a small mass of air, situated at A, will receive from the neighboring masses a lateral impulse changing into a vertical impulse which will be greater than the pressure downwards which it receives from the column of air AA'; a column whose weight is less than that of the adjoining column on account of its higher temperature and on account of the flow of a certain quantity of air from the upper region; this mass rises and thus there will be produced a lowering of pressure at A and also between A and B, at the surfaces of the earth, a gradient from B to A. This gradient is also a motor gradient, but as we see, the phenomenon is not so simple as in the preceding case, being that which we will designate by the name *motor gradient of the second order.*

Fig. 2.

Suppose now that with the same lower isobars we have the reverse distribution of temperatures from what we have considered; for example (Fig. 2) a temperature of 10° C. at *A* and 15° at *B*, (which is the case when the maximum pressure covers Europe and the minimum pressure is over the ocean.) The direct action of the temperature on the volume of air under consideration is no longer the cause of the production of the difference of pressure, which is due in this case to dynamic effects. We will therefore designate these gradients by the name *dynamic gradients.* They are found either as permanent conditions or when the difference of pressure between two planes is not constant.

Up to the present we have only considered the rectilinear movements of the atmosphere, but in consequence of the movements of the air relative to the earth's surface, the winds are deviated to the right of their course in the northern hemisphere and to the left in the southern hemisphere.

Furthermore, in cyclonic movements, the air moving in curves of small radius, it happens that the compound centrifugal force and the single centrifugal force, both making their effects felt in the whirls of the depression, tend to heap up the air on the right of the wind's direction, in our hemisphere, until the difference of pressure thus formed is great enough to counteract the centrifugal effect which tends to throw the air beyond its circle of rotation.

When the air moves under the influence of a difference of pressure, or by being carried with it, there is maintained or formed a difference of pressure with respect to the horizontal planes, and this difference of pressure is shown by the barometer and enters into the value of the measured gradient. Thus, when there is a relative movement, the dynamic surfaces of equal level differ from the static surfaces of level which are parallel to the earth's surface.

The gradient thus formed has, as we see, a very different origin from the gradients of which we have spoken, its effect being to oppose the resultant of the centrifugal forces in the

plane of the horizon which is directed normally to the wind's track.

These gradients, instead of producing movements, are their result, and, in contrast with the motor gradients, we will call them *resisting gradients.*

We come, therefore, to the consideration of three kinds of gradients:

The motor gradients of first and second orders.

The dynamic gradients.

The resisting gradients.

The effective action of the gradient on a wind of given velocity differs according to the following cases:

(1) For example, between the tropics and the equator, there exists near the ground winds directed towards the equator, and which in the northern hemisphere blow from the northeast. These trades are a consequence of the lowering of the pressure towards the equator which correspond to motor gradients of the second order caused by the difference of temperature. Now, by reason of the retardation of the wind with respect to the earth's rotation, the dynamic planes are less depressed than the terrestrial ellipsoid, and there results for us the production of a resisting gradient directed towards the equator. The trade wind, therefore, is not produced by the whole gradient observed, but by the difference between the observed and the resisting gradient.

(2) In the upper regions, on the contrary, the motor gradient of the first order is directed towards the pole and the air lags behind the diurnal movements; the resisting gradient, as before, is directed towards the equator; the acceleration imparted to the air is therefore due to the sum of the observed gradient and the resisting gradient. To measure the motor gradient, the surface of equal pressure must be referred not to the earth's surface but to the dynamic planes which are less flattened.

(3) In a barometric depression, it is interesting to separate, as much as possible, from the total gradient, that which belongs to the resisting gradient.

Knowing the wind velocity and direction at one place, we can calculate by Ferrel's formula the resisting gradient corresponding to this movement (neglecting the action of the rotation of the air around the center of the depression, which for large depressions is in general rather feeble in comparison with the value of the terms depending on the earth's rotation).

In subtracting the gradient thus found from the gradient observed, we obtain the motor gradient, that is to say, the one which gives to the air its movement and which can accelerate it if the whirl of the depression has not attained permanency.

It is evident that a depression having a given gradient is not in the same condition when the motor gradient dominates as when, on the contrary, the resisting gradient is the greater, the first condition belonging to a phenomenon which is developing.

(4) In a high pressure the motor gradient is in the same direction as the resisting gradient and, therefore, to have the effective motor gradient, it is necessary, as we have before done, to deduct the resisting gradient from the observed gradient.

It should be remarked that the centrifugal effect of the system independent of the effect of the earth's rotation, that is to say, the centrifugal effect which results from the inertia of the wind, following a spiral path around the center of maximum pressure, tends to drive the air outward, as does the motor gradient, and, consequently, to equalize the difference of pressure. It is thus opposed to the effect of the relative movement with respect to the globe.

We see, therefore, from these various considerations, that the relation existing at a given movement between the velocity of the wind and the gradient observed is not simple, even taking into account the time during which the gradient has been acting on the air.

In order to determine the true value of the motor gradient it is necessary to consider the radius of the trajectory of the air when this radius is small.

The author also wishes to call attention to a cause which tends to modify the velocity of the wind and which has not hitherto been considered in studies on the gradient; this is the dragging of the air by the friction of the superincumbent layers. Everything leads to the belief that the dragging acts in a certain degree upon the lower isobars and effects the formation of dynamic gradients which are evidently motors and which ought to be revealed by our observation. But the amount by which the dragging acts on the lower isobars completely escapes us so that we cannot say whether the measured gradient can give us, through the laws of gravity known at the present time, the wind velocity which we observe.

THE CLIMATIC HISTORY OF LAKE BONNEVILLE.*

R. DE. C. WARD.

As gauges of past climate there are no better standards than large enclosed lake basins of continental interiors, and from a study of these basins we shall undoubtedly gain much additional knowledge on the important subject of secular changes in climate. The most recent considerable contribution in this field is by G. K. Gilbert, on Lake Bonneville (Monograph I. U. S. G. S. 1890). It brings out many interesting facts in this connection.

The evidence of the former presence of a much larger body of water in the Salt Lake Basin attracted early notice from our western explorers, and in the last two decades the question has received much attention. The monograph here reviewed embodies a consideration of all the results thus far gained by field observations and theoretical discussion. It is worth noting that the Second Annual Report of the Geological Survey—the first report under the present Director—contained an essay by Mr. Gilbert in which a preliminary account of the study of Lake Bonneville, the presumable ancestor of Salt Lake, was presented; and since that time the completion of the monograph now issued has been borne more or less in mind by its author. The judicial quality of the discussion upon the more doubtful points is a natural product of mature deliberation thus permitted, every suggestion that is offered has evidently been scrutinized on every side. So serious is some of the climatic discussion that its reading must not be lightly undertaken.

The "Great Basin" of North America lies in the western third of the continent. On the north it borders the Snake, a large branch of the Columbia River, from which it is somewhat indefinitely separated, while on the south it is with even greater vagueness separated from the Colorado River. The steep eastern flanks of the Sierra Nevada constitute the western boundary, and the eastern is generally defined by the Wasatch Range. The area has roughly the form of a triangle, and is about 210,000 square miles in extent. It is marked by great aridity, the streams withering away in the desert plains, or feeding the intermittent mud flats (playas) and shallow salt or

* Abstract of J. K. GILBERT'S "Lake Bonneville." Monograph I. U. S. Geol. Survey, 1890.

alkaline lakes which are found there. The southern half of the basin is even drier than the northern. The cause of this extreme dryness is found in the prevailing winds which, on their way from the Pacific and in their passage over the Sierra Nevada, have precipitated much of their moisture and pass over this region as drying winds.

This Great Basin comprises within its boundaries probably a hundred lakes or playas, which are now separated from one another, but in a former more humid climate were largely joined together. The two largest of these former lakes have been named Lahoutan and Bonneville. Lahoutan, fed by the snows of the Sierra, occupying the western, and Bonneville, which once discharged to the north, the eastern part of the basin, with its water supply in the snow and ice of the Wasatch and Uinta mountains. The area of the Bonneville Basin is about one-fourth of that of the entire basin, or about 54,000 square miles, and the area of its water surface was 19,750 square miles, or somewhat less than that of Lakes Huron or Michigan. Its length 346 miles, its extreme width 145 miles, and its maximum depth about 1,050 feet. Almost all this vast area is now a desert. Great Salt Lake, the largest of the lakes of this former water area having an extent (in 1869) of only 2,170 square miles and an extreme depth of only 49 feet. This great desert plain which we see to-day at an elevation of 4,000 feet above sea level was a former lake basin, and by a study of its shore lines and other features the past history of the region has been clearly made out.

The occurrence of many alluvial cones along the bases of the mountain ranges, buried more or less by later lake deposits, at points where they were brought by the rivers which emptied into the lake, gives some clew to the pre-Bonneville history of the basin. It is clear from a study of these cones that lacustrine conditions arrest their building, for in that case the stream either builds a delta, or else its load of detritus is absorbed by the shore drift. As these cones reach nearly to the bottom of the basin and could not have been made in a large lake, the evidence is good that they were formed at an epoch of low water, and this is further confirmed by the fact that there seems to have been no outflow of the lake until a later, or Bonneville, epoch.

After a long pre-Bonneville time of low water, came a time of high water which however did not result in an overflow, as the

evidence from the shore line shows. After this came a period of perhaps complete dessication, as is shown by the unconformity between certain deposits on the lake bottom, and the difference in their character, the yellow clay of the first high water epoch being overlaid by masses of gravel and boulders which are evidently not of subaqueous deposition. This has been called the inter-Bonneville time of low water. The next change was a period of high water, which resulted in an overflow of the lake at Red Rock Pass, at the northeast corner of the basin, which was the lowest point that could be found, and a channel was here cut to a depth of 373 feet, first through alluvium and then through solid rock. While at its highest level, before the outflow had drained the lake, a shore line was cut by the waves which has been called the Bonneville shore line, and which makes the greatest expanse of the lake. This shore line is one of the marked features of the country, and cannot fail to be observed by everyone who travels through that region. It is about 1,000 feet above the level of Great Salt Lake, and 5,200 feet above the sea. As the Red Rock Pass channel was worn down, the level of the lake sank by degrees, and various other shore lines were cut, the most marked one being what is called the Provo shore line, which can be easily traced in all parts of the basin and far exceeds all the others except the Bonneville in strength. The height of this line above Salt Lake is 625 feet, and it is 375 feet lower than the Bonneville shore line, that difference of height corresponding to the depth to which the Red Rock Pass outlet was cut. The Provo shore line marks the level of the lake after the outflow channel had been most deeply cut. The period of dessication then set in with the resulting practical extinction of the old lake as at present.

Such, in a brief way, is the history of the Bonneville oscillations. It remains to summarize the theories which have been advanced in explanation of these phenomena. A possible cause for oscillation might have been the migration of divides, and diversion of rivers which would increase or diminish water supply, but a careful consideration shows that such a source is inadequate. The growth of the enclosing Wasatch and Uinta mountains, a process which is known to have occurred, might have increased the rainfall and water supply, but on the other hand these mountains do not seem to have been reduced in height, so that the dessication cannot be accounted for in this

way. Further, the history of the oscillations of Lake Lahoutan,* which are distinctly similar to those of Bonneville, show that there must have been a general and common cause in operation.

The appeal to an extended elevation and depression of the whole region of the Great Basin, which would affect all the lakes, cannot be upheld for lack of evidence. So we come next to the hypothesis that a change of climate was the cause. The connection of glaciers with the rise of water in closed basins has been suggested by Jamison, Lartel and Whitney, and further developed by King, Russell and Gilbert. This hypothesis rests on four analogies: *First*, Recency of the glacial and lacustrine periods, as shown by the preservation of their remains, such as shore lines and moraines. *Second*, The episodal character of the glacial and lacustrine epochs, the first coming after a time of stream erosion, when there was no ice or little ice; the second coming after a period of dryness. Both were therefore interruptions. *Third*, The division of the glacial epoch into two periods of advance, corresponding to the two stages of high water in the lakes. This analogy loses some of its weight, however, when it is seen that the highest authorities on the glacial epoch disagree as to the number of advances. Penck and Brückner believe that there were three epochs. James Geikie says four, the French geologists generally one, Upham, Newberry, McGee, and Chamberlin two, though they disagree in minor points, and Wright one. The weight that was formerly laid on this point must therefore be withdrawn to some degree. *Fourth*, The belief that, should the glacial conditions return to California and Utah, the lakes would also be restored. This, however, appears to lack sufficient foundation. A decrease of temperature alone would retard evaporation, the rivers and lakes would have greater volume, the snowfall would be greater and would, if the temperature were low enough, hold over through the summer, and the conditions would then be favorable for glaciers and the filling of the old lake basins. A rise of temperature alone would decrease the relative humidity of the air, increase evaporation, and decrease the volume of streams and lakes; less snow would fall, and it would be quickly melted, and the conditions for dessication would be present. An in-

(* See "Lake Lahoutan," Monograph XI. U. S. Geol. Survey, by I. C. RUSSELL. The studies on Lahoutan were made by Russell and other members of Gilbert's "Great Basin Division" of the Survey.)

crease of local vapor tension alone, would also tend to increase the volume of the streams and lakes, and a decrease of vapor tension to dry them up. Should an increase of temperature and a diminution of vapor tension come together, then the lakes and rivers would shrink, and a fall of temperature together with an increase of vapor tension would make them grow. But a rise of temperature and an increase of vapor, or a fall of temperature and a decrease of vapor would tend to neutralize each other, and the result would only be determined by the excess of one cause over the other. An elevation of the district would lower the temperature and increase the precipitation or the relative humidity, either of which facts would increase the water supply. On the other hand, a lowering of the region would have the opposite effect. Changes in the distribution of land and water, in the course of ocean currents, and in the direction of the general air current, would all have a marked effect. In some cases the glaciers and lakes might be similarly affected and in some cases differently. The whole subject is a very complicated one, and does not admit of definite statement. But it is evident that too much weight should not be given to the mutual dependence of lakes and glaciers.

It is seen, then, that the evidence of the dependence of the lacustrine on the glacial epoch, which is based on the bipartition of these two periods, and on the climatic conditions which might effect lakes and glaciers simultaneously, is not to be considered as having much weight. In place of these two arguments however, there is direct evidence which bears on this question, and this is of a more satisfactory nature. If the Sierra and Wasatch ranges should be elevated and glaciers should form on them, the general temperature of the whole district would be lowered. A similar result would occur were glaciation increased by the encroachment of the Pacific on the coast of California, or by the lowering of the temperature of the Pacific, or by a change in the direction of the prevailing air current. Glaciation increasing with a lessening of solar heat if these lakes were contemporaneous with the glacial epoch, they must have occurred during times of relative cold. If this was the case, then the fauna of the lakes should bear evidence of it. Now a study of the molluscan life of the lakes Lahoutan and Bonneville, which may be grouped together as a single homogeneous faunal district, reveals the interesting facts that of all the species of fresh water shells existing and fossil which have

thus far been collected in these districts, forty-three in number, five-sixths of the fossil forms are known in the recent waters of this area, and that the fossil shells corresponding to species existing to-day are smaller than those of the present time. The explanation of this difference in size was sought in the effect of cold, or of salinity, and an examination of the existing shells living in waters of different temperature revealed the fact that the specimens from the colder lakes are smaller, and the same was found to be true of specimens living in more saline waters, they being smaller than those inhabiting fresher waters. Lake Lahoutan had no outlet and it is therefore probable that the change in its fauna was caused by increase of salinity. But Bonneville had an outflow during its second high water epoch, and an examination of its shells which lived in the lake during this period shows them to have been of a small size; the depauperation in this case may therefore be regarded as due to a colder climate. The evidence from the vertebrate life is valueless.

A second argument favoring the correlation of the ice and water maxima is found in the study of the glacial moraines around the shores of the two lakes. On the western front of the Wasatch range are three moraines which descend to the level of the Bonneville shore line, and the two which are best exposed to view, show no shore lines, which would have been the case had the ice reached its maximum extent during or before the epoch of the Bonneville shore line. The third moraine, which is partly covered with alluvium, records a time when the lake stood higher than the Provo shore line. If the maximum of the glaciers had come after the close of the Provo epoch, then this moraine should rest on alluvium instead of being covered with it. So the evidence of the glacial and the lacustrine maximum points to the same conclusion. Similar evidence has been found by Russell (Eighth Annual Report U. S. G. S. pp. 261–394) in his study on the basin of Lake Mono. Four moraines from the Sierra Nevada glaciers descending to the highest shore line of that lake show that the maximum water level came after the glaciers had retreated from their most advanced position.

Combining the result from Lake Mono with that from Bonneville the conclusion reached is therefore this: The epoch of greatest glaciers came within the second period of lake expansion, but came somewhat earlier than the epoch of greatest

water supply. This lagging of lacustrine behind glacial changes being a natural consequence of the growth and melting of the ice. The evidence from the fauna and the moraines confirms the presumption derived from the recency and the exceptional nature of the lakes and glaciers, that the two phenomena were coordinate and synchronous results of the same climatic changes. It follows as a corollary that the glacial history of the region was bipartite.

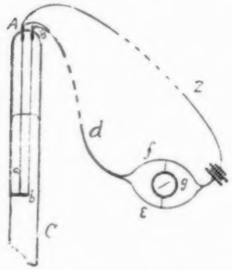
HARVARD COLLEGE, June, 1891.

OBSERVATIONS AT A DISTANCE.

By T. PROCTOR HALL.

The great expense and frequent hardships in connection with the maintenance of a meteorological observatory on a mountain peak have hitherto prevented us from getting an accurate knowledge of the condition of the higher strata of the air, though the importance of that knowledge is evident. In some such cases it may be practicable to establish, in connection with a regular observatory at a lower level, a meteorological mission-station at which a regular series of observations will be taken without more than a semi-occasional visit from the observer. By the electric anemograph the rate and direction of the wind may be recorded at almost any distance. Next in importance comes the temperature and pressure of the air, which may be observed at a great distance in the following way:

In the top of the barometer tube *c* are fixed two fine platinum wires *a b*, whose resistance is about 20 ohms per meter.



When an electric current is passed from *a* to *b* through the mercury, a change of 1-20th of a millimeter in the height of the mercury makes a change of 2,000ths of an ohm in the resistance of the wires. This resistance is measured by a bridge-and-mirror galvanometer *g*. The circuits are completed by the ground wire *z* and a cable *d* containing two insulated wires of low and nearly equal resistance, twisted round each other. Under these conditions it may be fairly assumed that any change in the temperature or induction will affect the

two wires of the cable equally, and the difference between the resistances of the external parts of the two circuits $e\ d\ B\ b\ a\ A\ z$ and $f\ d\ A\ z$ will remain almost absolutely constant; the galvanometer will therefore be affected only by changes in the resistance of the wires a and b.

To use this instrument we must know—

1. The resistance per cm. of the wires $a\ b$ and their temperature coefficient.
2. The reading of the bridge-and-mirror galvanometer at any one known temperature and pressure.
3. The correction for temperature of the barometric column.

A slight inaccuracy may arise from capillarity.

For reading temperatures a thin strip of silver or other unoxidizable metal is connected in the same way with a galvanometer and its resistance measured.

WORCESTER, MASS.

OCEAN FOG.

By E. B. GARRIOTT.

The importance of a better determination of the causes which seem to produce fog off the coast of the United States, and the acquirement of a knowledge of the general meteorological conditions which attend its appearance in and about New York harbor, became apparent to the writer a decade of years ago, when, in response to inquiries, he was called upon to express an opinion as to the probable continuance of fog which occasionally paralyzed local maritime traffic. Investigation showed that, as a rule, the fog of that region was swept in from the ocean by winds in the east quadrants of areas of low barometric pressure, or general storms, which advanced from the interior of the continent, and that with the shift of the wind to the west and northwest following the passage of the storms to the eastward the fog was dissipated. This knowledge made it possible to calculate not only the time of the disappearance of fog with a great degree of certainty, but also to foresee the conditions favorable to its development. In later years a study of the marine reports collected by the Signal Service led to the discovery that the fog of the banks of Newfoundland and of the steamship tracks to the westward was also dependent upon the storms which advanced from the American Coast north of the fortieth parallel, and an examination of vessel reports during the last four years

has shown that in exceptional cases only does fog appear in that region unattended by the general meteorological conditions referred to.

The apparent cause of the fog of the banks of Newfoundland and of that portion of the ocean lying between the fortieth parallel and the American Coast is found in the condensation of moisture in warm air, drawn northward from over the Gulf Stream by southerly winds in the east quadrants of areas of low barometric pressure, by contact with the ice fields of the Banks of Newfoundland and the cold Arctic current which flows down the coast, and the greater prevalence of fog during the summer months is attributed not only to the presence of large quantities of Arctic ice over and near the Grand Banks during that season, but also to the greater capacity for moisture of warm air. Another probable cause of its more frequent occurrence in summer is the distribution of atmospheric pressure over the north Atlantic Ocean. In winter the Iceland area of low barometric pressure causes a larger proportion of colder, dry, westerly, continental winds whereby the difference in temperature necessary to condensation is not produced, while in summer the Azores area of high pressure occasions a greater prevalence of warm, vapor-laden winds from over the southern ocean. The more northerly course of the Gulf Stream in summer is also a probable factor of the fog of that season on the Grand Banks.

That these fogs can be predicted with the same degree of accuracy that attends the weather forecasts for the Atlantic coast states has been proved. It is known that a type of storms that advance to the American Coast from the interior produces a large inflow to the region of fog of sea air from the Gulf Stream possessed of the temperature and containing the moisture necessary to the precipitation of fog. As storms of the class referred to are well-defined and have a slow progressive movement the fog of the Atlantic Coast can be predicted for one to two days, and that of the Grand Banks for two to three days in advance. The value of the predictions lies not only in the fact that the occurrence of fog can be anticipated for the benefit of mariners, but is more largely due to the circumstance that the fog-banks can be avoided. The ordinary weather prediction does not to any great extent convey the manner or means of avoiding the damaging results expected from excessive precipitation, great cold, frost, etc., while in the case of fog it is known that it does not occur south of the fortieth parallel,

save along the immediate coast, and a prediction of fog would carry with it a warning to commanders of trans-Atlantic steamships to follow a more southerly course, or that plotted and recommended month by month in the Hydrographic Office *Pilot Chart*, and thus avoid not only possible disaster from ice or collision to the vessels they command, but also lessen the danger to fishing craft on the Grand Banks which are not infrequently run down by steamships during dense fog.

WATER SPOUTS.

By Professor Cleveland Abbe.

Having sailed from New York the 16th October, we had first a few days of westerly winds and moderate sea, and then fell upon a region of easterly winds, generally south easterly, and with every indication that we were in the easterly portion of a cyclonic region, the storm centre being 300 to 500 miles to the westward. From such observations as we were able to make on ship-board, it was concluded that the storm centre, which on the 20th October was south westerly, was slowly moving to the north eastward, and would overtake us and pass beyond. This it apparently did, and disappeared from our observation on Friday the 25th. Meanwhile we experienced warm south easterly winds, with numerous showers of rain and occasional squalls of wind.

On the morning of Tuesday the 22nd, we were favored with a remarkably fine development of waterspouts. About 9 A. M., occasional whirls of spray were seen on the surface of the sea, at points bearing between S S W and W S W. These whirls, and the subsequent waterspouts in that region, were all on the N. E. side of a region of cloud and rain, the interior of which constituted a veritable rain squall. The N E side of this region, as seen from the vessel looking S W, was bordered by rolls of low scud upon which the sun shone; but beyond and below this the clouds, being mostly in the shade, had the dark blue tint that belongs to the rain-cloud and the rain. The waterspouts apparently originated in the scud clouds, which, as I have just said, formed the N. E. border of the squall proper. These scud clouds were moving towards the N. W., and there-

* From the Bulletins of the U. S. Scientific Expedition to West Africa, 1889.

fore nearly perpendicularly to our line of sight. By 10 A. M., the conditions for the formation of the waterspouts, namely, the long axis extending down from the clouds, had become very favorable; so that from 9:30 until 10:15 there was a continued succession of such spouts, forming and disappearing in this portion of the horizon. At one time as many as five and seven were visible simultaneously, and the total number that formed and disappeared was estimated at about thirty by some, but at about twenty by myself. The first ones formed were at a distance from us estimated at about four miles; the last ones at a distance of two or three miles. As the squall grew in dimensions and approached us, it was hoped that spouts would be formed much nearer; and in fact one was observed endeavoring to form in a mass of rain, at a distance of scarcely a quarter of a mile on our starboard bow. A number of drawings of these phenomena were made, and some photographs were taken. The latter, however, are not considered very successful, owing to the insufficient contrast. Among the features noted in these waterspouts, which will, I think, deserve to be ranked as general phenomena for all such spouts, are the following:

1. The whirling motion of all the spouts took place in the same direction so far as could be judged, and was that ordinarily called "counter clock-wise."

2. The general motion of the waterspouts as a whole was from left to right, or from the S. E. toward the N. W., and therefore counter clock-wise, considered as a partial rotation round the centre of the rain squall.

3. As this rain squall was essentially a part of the formation of a cumulus cloud out of a mass of what would otherwise have been called low scud, and as no waterspouts, or any tendency to the formation of such, were seen on the other side of the cloud after it had overtaken us, as it did at 10:30, I conclude that the formation of the waterspout requires a special upward ascending current due to a special bouyancy in one portion of the cloud; and, other circumstances being the same, such buoyancy must generally be found, as in this case, on the sunny side of the cloud, and is due largely to the action of the sun's heat on the surface of the cloud, combined of course with the buoyancy of the ascending cloud masses. As regards the individual tornadoes or waterspouts, it is very evident that a less rapid whirl was required to form the little saucer-shaped mass of spray at the ocean's surface, than was required to form the axial cloud

that reached down from above. There were, I think, more cases in which the spray appeared first, before the cloudy axis was visible, than the reverse cases; but there was nothing to show that the ascending movement started at the ocean's surface and carried the sea water upward into the cloud. On the contrary, all the details of the phenomena showed that the spray carried up from the surface of the sea attained only a height of perhaps 100 feet, and was then thrown out and descended from the rim of the saucer. In some cases the axial cloud apparently descended into and was lost sight of in the lower spray, but its appearance was such that it was always possible to distinguish it from the spray. The axial cloud invariably began its formation at the lower surface of the general cloud, and stretched downward by spasmodic efforts, gradually increasing its length until it perhaps reached the spray, and then began retreating, forming and reforming several times, until finally either a permanently steady, tubular cloud was formed, which would continue in sight bending and swirling about for several minutes; or, as in many cases, after several efforts, the whirl broke up and no permanent tube was formed. When the cloud was about to shoot down to a considerably lower level than it had hitherto attained, the shooting was generally preceded by the appearance of an exceedingly fine axial line; and when the tubular cloud shot down, as seen by the distant observer, I should say that this apparent descent was merely the sudden expansion to a visible diameter of the fine line that had just preceded it. The appearance of this fine line was very similar to that of the sting of a bee protruding from its sheath; and frequently I saw this line shoot down and disappear a number of times before the rapid whirl was finally able to produce an axial cloud of permanent size. In many cases the axial cloud itself showed a fine line down its centre, the cloud itself being whitish while the central line was either dark or bright, depending upon the background against which it was seen. This agrees perfectly with the accepted theory of the formation of the spouts, according to which the long narrow cloud is not a solid mass of cloudy material, but rather a hollow cylinder; so that when one looks through it the central portion is much more transparent than the edges.

At numerous points, from the general cloud under which the waterspouts were formed, there were descending showers of rain; and scud, from which rain descended, afterwards formed

between us and the tornadoes, and finally again off the port side of the vessel; so that by 10:20 we were enveloped in a heavy rain, with the wind from the S. E., or starboard side. This continued ten or fifteen minutes, after which it slackened up. In hopes that we might get near enough to the whirl that surrounds the spout, and experience an appreciable depression of the barometer, I carried an aneroid in my hand; but in no case was I able to see that it was affected by any or all of the spouts. The barometer at 9 A. M. had read 30.12; at 9:35 it read 30.08; at 10:20, after the rain squall had struck us, the pressure rose to 30.20; and at 1 P. M. had sunk again to 30.18. These fluctuations are those that attend ordinary rain squalls, and have, I suppose, no connection with the waterspouts as such. It was not to be expected that the barometer would fall except within the whirling wind, and possibly within a hundred feet of the axes of the waterspouts.

It has frequently been supposed that the discharge of a cannon will break up a waterspout. On the present occasion, it so happened that a six pounder was ordered to be discharged in order to clean it out; and this took place in the midst of the display of waterspouts, which were then three or four miles distant. The discharge of the cannon was followed within a few seconds by the breaking up of one of the spouts, but others remained, and several others were formed a few minutes afterward, so that the breaking up of the one can only be considered an accidental coincidence; nor is there to my mind any conceivable reason why the discharge of a cannon, at a long distance from a spout, or even the firing of a cannon ball through the spout, should be considered likely to have any appreciable influence on the great mass of revolving air.

The general discussion of the mechanism of a waterspout has been so well given by Ferrel in his newest work "A Popular Treatise on the Winds, by Wm. Ferrell, New York, 1889," that I need only say that everything observed by us on the 22nd October fully confirmed the views therein set forth by him.

On the next day, the 23d, about 8:30 A. M. the clouds looked favorable for a repetition of the waterspout phenomena, and beautiful mammiform clouds were indeed seen developing into the axial clouds of waterspouts. One of these lasted over twenty minutes, but did not reach any considerable distance down toward the sea, nor was any whirl of ocean spray to be seen beneath it.

Of all the spouts seen on the 22nd, the largest appeared to have a horizontal diameter of about one-tenth its vertical height. This one also lasted the longest, and, after breaking up was apparently followed by rain to a greater extent than in the other spouts. The narrowest of these spouts had an apparent diameter of about one hundredth part of its height. The general height of the tops of the spouts was pretty uniform like that of the scud to which they belonged, and was, I should estimate about 1200 feet.

CORRESPONDENCE.

ON RAIN FORMATION.

To the Editors:—In your issue for April, I notice on page 689, some remarks about certain views supposed to have been advanced by me, which may call for a little explanation. "It is a little strange," says Professor Hazen, "that Mr. Velschow has fallen into a serious error in the same line. On seeing moisture collect on the side of the jar, he thought it was squeezed out, so to speak, by compression, and upon this view he founded an elaborate theory of the formation of rain by the descent of masses of air which squeezed out the moisture by compression."

Professor Hazen has been brought up in the belief that the condensation of moisture, produced by compressing moist or saturated air, is entirely due to contact between the cold surface of the jar and the air which has become warmed up by compression, and no consideration whatever will induce him to admit that it might possibly be due to something else besides, or that it is only partly due to contact. That such, however, must actually be the case I conclude from the result of expanding saturated air, and it is not a little singular that Professor Hazen has taken the trouble of repeating my experiments in this regard, with exactly the same results and still can not see, or rather, he shuts his eyes and will not see, that my argument is perfectly logical.

In your Journal, August, 1890, he writes (page 212): "In some recent experiments a receiver, containing air at about 95 per cent. relative humidity, was connected with an air-pump, and the air suddenly exhausted to the extent of two inches, equivalent to an uptake (*sic!*) of about two thousand feet; no fog was produced in the receiver, and there was an actual dimi-

nution of relative humidity. These experiments have been repeated, again and again, with great care, and all of them go to show that the ordinary views of condensation, due to expansion in an up-rushing current, are very much at fault and entirely erroneous." As this is a statement about experiments carried out by Professor Hazen himself, I may venture to suppose that he has some confidence in their correctness, or, at least, that he will not repudiate them without showing sufficient reason, and I shall allow myself to show that Professor Hazen has hereby himself admitted that condensation is produced by compression of saturated air. If, namely, it be admitted that there is an "actual diminution of relative humidity" by the air being expanded, there must, necessarily, be an actual increase of relative humidity by the same air afterwards being compressed, or how are we otherwise to come back to *status quo*? If both processes, expansion as well as compression, have the effect of making the body of air experimented on drier than it was before, we should, by continued manipulation, succeed in annihilating the moisture the air originally contained. Indeed, if the air was in connection with water surface we should, by moving the piston rod up and down in the glass cylinder a sufficient number of times, cause it, by continually making it drier and drier, to absorb an unlimited quantity of water, and still end by being perfectly dry. But common sense will tell us that by bringing the piston back to its original, or starting, position after however many strokes, we must find the air under the piston in exactly the same condition as it was when we started operations. If, therefore, we are reasonable enough to acknowledge that there must be an actual increase of relative humidity when we compress moist air, it follows, of necessity, that by compressing saturated air the air must either become supersaturated or give off a part of its moisture by condensation; and by applying the results of these physical experiments to the phenomena of the atmosphere, we must conclude that the only possible way of accounting for rain in cyclones on dynamical principles is by assuming that the upper moist air of the regions of the cirrus clouds gives off moisture by compression when it sinks to a lower level, as the stir or commotion in the air would prevent it from remaining in the state of unstable equilibrium, of being supersaturated. * * * * *

FRANCIS A. VELSCHOW, C. E.

BROOKLYN, May 16, 1891.

[We find ourselves obliged to curtail Mr. Velschow's letter.]

WIND AND SHOWERS.

To the Editors:—In every case thus far this season, in this locality, the wind has blown directly away from all showers that have appeared, no matter what their direction, extent, or how far away on the horizon they have been. In several instances this outblowing wind has extended several miles, not only beyond the limits of the rainfall existing at the time but even beyond the cloudiness attendant upon the storms. In no case has there been any evidence of an indraught toward the storm, but on the contrary, the winds have been in the opposite direction, and as a rule have been quite brisk. Yesterday, for example, a thunderstorm passed from west to east along a line whose nearest approach to the village was about three miles. As it appeared in the southwest the wind was brisk from that direction and veered slowly southward and then eastward, until as the storm disappeared in the southeast the vane was still pointing directly toward it. The same thing happened also in the case of another small but energetic storm which passed at a distance of three or four miles north of the village. There was a brisk breeze directly from it, as long as it remained in sight, the vane pointing successively northwest, north and northeast, slowly veering as the storm passed along the horizon, there being but few clouds and scarcely any rain at this point during its passage. I have noticed frequently the puff of wind in advance of an approaching storm just before the rain begins to fall, but my attention has not until recently been called to a brisk outflow of air extending several miles in every direction from such local storms. Whether this is due to some peculiarity in the storms of the present season I am unable to state. It certainly is new to me and appears to be wholly irreconcilable with the indraught and uprush theory of the origin of our local summer storms.

M. A. Veeder.

Lyons, N. Y., June 17, 1891.

CURRENT NOTES.

Ice and Current off Belle Isle. — Mr. Michael Colton, keeper of the Belle Isle lighthouse, reports as follows:

In March and during the latter part of February there was a strong current running from the Labrador shore in a S E'ly direction, setting occasionally, with southerly winds, toward E by S. During all of this time there was clear water from Barge

Bay, Labrador, down as far as can be seen; there is always considerable open water when the current sets toward SE and E by south. The current seemed to run swifter by night than by day, as at times a good deal of ice would come down out of the strait in the evening, and next morning it would tend off to the SE, even though the wind were from that direction. No heavy northern ice has come into the strait as yet, owing to prevailing S and SW winds. If there is any heavy ice to the southward off the banks, it must have passed this coast a long distance off shore, as only one iceberg has been seen during the entire winter—one that grounded toward the end of January about three miles E SE of White Island, in fifty fathoms.—*Pilot Chart* for June.

METEOROLOGICAL NOTES. — Cherra Poonjee, in the Khasi Hills, Assam, has long been given in the books as the place having the greatest rainfall and the mean annual rainfall is frequently given as 600 inches. In his "Climates of India," Mr. Blanford gives the annual rainfall at 474 inches. A later critical examination of the various records causes him to put the figures at about 500 inches, possibly a little above. 40.8 inches fell on June 14, 1876; 63 6 inches on the 14th and 15th, and 79.0 on the 12th to 14th.

—A heavy snowfall occurred in Southern England on March 9 and 10, 1891. It extended in a band about 120 miles wide from the South of Ireland to Holland. It was deeper in Cornwall and Devonshire than elsewhere, averaging there about two feet.

—The dry weather of the latter part of April and the first of May brought on a series of forest fires which were unusually severe for spring. Michigan suffered most severely and, though the fires were a hundred or more miles to the north of us, the smoke at Ann Arbor was often very thick and sometimes the odor of burning pine could be detected in the air. It is sometimes claimed that the smoke of battle brings on a rain; smoke from the northern forest fires does not even produce clouds—the first step toward a rain. The heavy forest fires not only occur in dry weather but actually seem to intensify the drouth. The rain of the 21st and 22d of May extinguished the greater part of the fires but they were not fully extinguished until the heavy rains of June 3d and 4th. The severest fires of previous years in Michigan have been in 1828, 1853, 1871, 1881.

Royal Meteorological Society.—The usual monthly meeting of this society was held on Wednesday evening, May 20th. The following papers were read:

1. On "The Vertical Circulation of the Atmosphere in Relation to the Formation of Storms," by Mr. W. H. Dines, B. A., F. R. Meteorological Society. After giving an outline of the circulation of the atmosphere, the author refers to the two theories which have been suggested to account for the formation of storms, viz. (1) the convection theory, which is, that the central air rises in consequence of its greater relative warmth, this warmth being produced by the latent heat set free by condensation, and (2) the theory that the storms are circular eddies produced by the general motion of the atmosphere as a whole, just as small water eddies are formed in a flowing stream of water. The author is of opinion that the convection theory is the more probable of the two, but more information about the temperature of the upper air is greatly needed.

2. On "Brocken Spectres in a London Fog," by Mr. A. W. Clayden, M. A., F. R. Meteorological Society, F. G. S. During the dense Fogs in February last, the author made a number of experiments with the view of raising his own "spectre." This he ultimately succeeded in accomplishing by placing a steady lime light a few feet behind his head, when his shadow was projected on the fog. He then made some careful measurements of the size and distance of the spectre, and also succeeded in taking some photographs of the phenomenon.

3. "An Account of the 'Leste,' or Hot Wind of Maderia," by Dr. H. Coupland Taylor, F. R. Meteorological Society. The 'Leste' is a very dry and parching wind, sometimes very hot, blowing over the island from the E N E or E S E., and corresponds to the Sirrocco of Algeria, or the hot north winds from the deserts of the interior experienced in Southern Australia. During its prevalence a thin haze extends over the land and gradually thickens out at sea until the horizon is completely hidden. It is most frequent during the montns of July, August and September, and usually lasts for about three days.

Mr. Shelford Bidwell, M. A., F. R. S., exhibited an experiment showing the effect of an electrical discharge upon the condensation of steam. The shadow of a small jet of steam cast upon a white wall is, under ordinary conditions, of feeble intensity and of a neutral tint. But if the steam is electrified, the density of the shadow is at once greatly increased, and it

assumes a peculiar orange-brown hue. The electrical discharge appears to promote coalescence of the exceedingly minute particles of water contained in the jet, thus forming drops large enough to obstruct the more refrangible rays of light. It is suggested that this experiment may help to explain the intense darkness, often tempered by a livid yellow glow, which is characteristic of thunderclouds.

NOTES ON TAMAULIPAS:—Consul Richardson, of Matamoras, says, in the *Reports of Consuls* of the United States, No. 127:

Everyone knows the exceeding fertility of the soil and the adaptability of the climate to most of the products of the temperate and torrid zones. There can be no soil anywhere better than that which is found throughout the entire State of Tamaulipas, but it has been allowed to stand fallow year in and year out. The people are understanding more fully than ever that they are no longer altogether dependent on rains for any given crop. Streams are more numerous in this State than any other State in Mexico, and have been waiting for centuries to be turned into irrigating ditches. The more enterprising are now earnestly discussing irrigation, and this discussion is assuming practical form. Efforts have been made, but with poor success, in the direction of damming the San Juan River above Camargo. A more extensive scheme is on foot to distribute the waters of the Rio Grande throughout this valley. This scheme, if carried out, will unlock the treasures of the valley and give the people something which will make their trade more valuable.

This year has been disastrous for the rancheros, owing to the unprecedented drought. The staple crops, such as corn, cotton, and beans, are almost wholly cut off. Some cane plantations along the river that have been cared for are giving a fair yield. A trip to Brulay's sugar plantation and refinery, on the Texas side of the Rio Grande, revealed to me just what irrigation will do. It is the opinion of Mr. Burlay that there is no method of watering for this soil that equals nature's. He gets the best results when rains are frequent, but is sanguine that cane-growing, with irrigation and under the bounty system, can be made very profitable. Under the burning sun of this latitude and inadequate cultivation the soil, especially after irrigation, becomes baked hard, and the planters and farmers, like so many of their brethren in the United States, have not learned the important lesson that the best substitute for water is a fre-

quent stirring of the soil about the roots of the plant, as, indeed, it is a necessary accompaniment of water.

"There seems to have been a wide-spread impression that the region of the lower Rio Grande and the coast of Tamaulipas is unpleasant and unhealthful. I doubt whether any climate in this latitude (from 24° to 27° north) and at this altitude is more salubrious. There is no paradise on earth, nor is there any climate so bad that it does not have its compensating features. Suddenness of change in temperature and humidity is its main infelicitous feature, and here, doubtless, we have the cause, so far as climate can be a cause, of the prevailing lung diseases; but this same cause is found through the interior of the United States from the Dakotas to Mexico and the Gulf, and, if it be true—which I cannot concede—that there are more lung diseases here than in the belt of our country to which I have referred, we may account for them on purely physical and hygienic grounds. When deaths which may be attributed to these causes are eliminated, it will be found that the major part occur in first and second childhood. From July 1 to December 1, 1890, there were in the city of Matamoras 114 deaths. Of these 24 were infants and very old people. The infant mortality is due to inadequate care and ignorant midwifery; 19 died from small-pox, which, under proper sanitation, might be entirely eradicated; 25 from brain diseases, "in large measure," says a physician of wide experience and long residence in Matamoras, "due to fast living;" and 20 to consumption. These cases of consumption are found among those people who inherited enfeebled constitutions, who spent their inheritance, and then evidently expected to conduct their daily lives in utter disregard of the most commonplace rules of hygiene without paying the penalty. Of course, it is undeniable that the sudden and spiteful changes of temperature make lung diseases common, but they are made much more common by purely human causes. I find, however, resident foreigners here and across the Rio Grande, in Brownsville, speaking in enthusiastic terms of the climate—even those who have resided here long enough to become fully acquainted with its shortcomings.

WATERSPOUTS.—A number of reports of waterspouts have been received during the past month, especially in the region where these phenomena occur so often, namely, between Key West and Bermuda. A supplement to the Pilot Chart for

March, 1888, described as many as forty waterspouts that were sighted off the Atlantic coast of the United States, from Cuba to the Grand Banks, during the two preceding months, and within this region they are reported occasionally during every month of the year. The symbols plotted on this Chart indicate where each spout reported in the North Atlantic was sighted, but as some of the reports refer to other oceans, whilst others are often received too late for publication, it will be of interest to quote a few recent reports, arranged according to date.

March 30, at 11 A. M., about 15 miles east of Corvo Island, Azores: Waterspout rotating with the sun and moving SE. at rate of about 3 knots. Temperature of air 60°; water 62°. Barometer, 30.06.—Br. S. S. "Federation," Capt. Mars.

April 25, 12:30 P. M., lat. 30° 30′ N., long. 76° W.; Weather thick at times, with frequent rain squalls. Vessel suddenly struck by a water-spout, thrown on her beam-ends, boat carried away, deck flooded. Was obliged to cut away the main-mast to right the vessel.—Am. schr. "Baltic," Capt. Dyer.

April 28, — P. M., off Port Limon, Costa Rica: Strong SW. wind and heavy rain, with numerous waterspouts, as we approached land.—Br. S. S. "Alvena," Capt. Evans; report by Second Officer Segrave.

April 30, waterspout, lat. 52° N., long. 20° W.—Br. S. S. "Minia," Capt. Trott.

May 5, Bermuda, large water spout.—Bermuda Royal Gazette.

May 5, 6 P. M., lat. 24° 20′ N., long. 82° 21′ W., waterspout about 4 miles to the SSW., rotating with the sun and traveling NW. by N. at rate of about 6 knots. The appearance of the spout was followed by a cold current of air and heavy rain showers and a shift of wind from E. to NNE. Barometer, 30.08; cumulo-stratus clouds to the SE., SW., and NW., moving slowly toward NE.—Am. Bg. "John C. Noyes," Capt Karlsteen.

May 6, lat. 26° 04′ N., long. 80° 03′ W., a large waterspout.—Am. Sch. "Illinois," Capt. Pière.

May 6, lat 28° 09′ N., long. 75° 56′ W., sighted a waterspout; wind SW., moderate; cloudy, with lightning.—Ger. Bk. "Libertas," Capt. Schultz.

May 10, lat. 17° 20′ N., long. 78° 50′ W., waterspout.—Am. schr. "Maggie Cain," Capt. Meyes.

May 15, 11:30 A. M., lat. 33° 45′ N., long. 76° 30′ W., two very large waterspouts were observed about a tenth of a mile to the

SW'd. Very heavy rain, thunder and lightning. (For further details see weather review.)—Br. S. S. "Godolphin," Capt. Millington.

A blank form issued by this Office contains brief directions regarding the observations of special interest in this connection, and masters of vessels are urged to make their records according to the form indicated. Sketches, however rough, may often contain valuable information, and an attempt should always be made to illustrate the various stages in the formation and disappearance of a waterspout, with a statement regarding the time of each sketch and the bearing and distance of the spout. —*Pilot Chart for June.*

Professor Langley on Aerodynamics.—Professor Langley, secretary of the Smithsonian Institution, stated to the National Academy of Sciences, at its April meeting in Washington what was stated at the Patent Centennial meetings, that the problem of aerial navigation was likely to be speedily solved. He said subject he presented would cause surprise, as it was one the discussion of which had been confined more to the sphere of charlatanism than that of science. It is the subject of artificial flight, the propelling through the air of bodies heavier than the air. The perpetual miracle of a soaring bird was so familiar, he said, that it ceased to excite wonder. About five years ago he resolved to experiment in the matter, and, with the pecuniary aid of a gentleman, since dead, he had set up in the grounds of the Alleghany Observatory a whirling machine on a scale never before tried. Its use was to create an artificial wind. Its diameter was 60 feet, and it was driven by a steam engine of 10 or 12 horse power.

There was hardly anything, he said, in which statements of men of most honored names were to be taken with more caution than statements regarding aerodynamics, because there was so little founded on actual experiment. In this connection he referred to a paper by eminent French physicists in which it was held that in order to calculate the work one must put out to fly, it must first be determined how much work is required to merely suspend the body in the air. The conclusion solemnly reached is that a swallow to fly 40 miles an hour must exert one-tenth of a horse power, an eagle 10-horse power and an Egyptian crane, weighing 40 pounds, about 40-horse power. To suppose that an eagle or buzzard is as strong as 12 or 13 horses

was absurd, but the idea seemed not to trouble these writers at all.

Professor Langley said the first experiment he made was to test the question: Does it require more power to move laterally than to stand still in the air? He explained how he had suspended a flat brass plate from the arm of the whirling machine by a spring. When the machine was put in motion and the plate encountered an artificial wind, going 40 miles an hour, the spring, instead of elongating, actually shortened, showing that the weight or power required to suspend the plate was less when in motion than when it was standing still. This he considered was demonstrative evidence that there had been some gross misconceptions on the subject. After it was done, it became apparent at once that what occurred should have occurred.

Professor Langley said he then began the study of another matter connected with it. He found that the brass plate, when placed horizontally and moved forward laterally, sank to the ground slowly, as if the air had become like dense cream or butter. He illustrated by referring to the case of a man skating over thin ice. He supposed that the man went over 100 cakes of ice in a second, each cake being of a mass equal to his own. In that time, he said—speaking approximately—the ice would sink or yield only one one-hundredth as much as it would if he had stood during that time on one cake. By sufficiently rapid progress, he said, one could go over the most yielding surface without bending it much. He said the poet's figure of swift Camilla's flight o'er the unbending grain was scientifically possible.

Professor Langley further illustrated by means of a simple apparatus. He had a thin, narrow slat or plane of wood about three feet long and two inches wide, from the centre of which projected a handle about two feet long with a small brass knob on the end of it. First, he let the slat, with the handle downward, fall from his hand while holding it stationary. Then he whirled the stick between the palms so that the horizontal plane or slat was revolved, and let it fall while whirling. It was obvious that it took a second or two more to fall four feet while in motion than when it was dropped from the hand without motion.

Professor Langley explained various experiments made with his whirling machine, and the delicate and ingenious apparatus by which the results were recorded. As a conclusion of his experiments he said that the amount of power required for arti-

ficial flight was perfectly attainable by the steam engine we now possess. The amazing thing demonstrated by his experiments was that the faster you go the less it costs in power, and one-horse power will transmit a much heavier weight at a rapid speed than at a slow one. Professor Langley showed, by means of a table on the blackboard, results he had obtained in figures. With the plane at an angle of 45 degrees with the horizon, moving at the rate of 36 or 37 feet per second, at an expenditure of 2,438 foot pounds per minute, one-horse power would carry through the air 15 pounds, while with the plane at an angle of one degree, moving at the rate of 82 feet a second, at an expenditure of a little over 100 foot pounds of work per minute, a horse power would carry 333 pounds through the air.

He did not say that man could traverse the air, but under certain conditions and with our existing means, so far as the power is concerned, the thing was possible. The difficulties, he said, would be in getting started, in coming down to the ground again, and in guiding one's self through the air. Nature has supplied an instinctive intelligence in the bird to balance and guide itself. He did not question that man would ultimately acquire it. He thought aerial navigation would pass out of the sphere of charlatanism and into the hands of engineers in a short time, possibly months instead of years. He believed they would see something notable come from it. Mr. Maxim, the inventor of the machine gun, he understood, was making experiments, and had reached results similar to his own.

Temperature and Rainfall Compared with Cotton Production in Texas.—Texas produces nearly one-fourth of the cotton grown in the United States, and on account of the importance of this crop, data have been compiled which are published on another page, showing the normal monthly temperature and precipitation, and the departures of the current temperature and precipitation from the normal, for each month during the growing year (that is from the time one crop has finished its growth until the next is ready for harvest) for eleven years, from 1880 to 1890 inclusive, for the agricultural portion of the state. The total acreage in cultivation, and the yield per acre and total annual yield of cotton produced in the state in each of these years is given. The monthly departures have been deduced from five stations and over, where complete year's records could be obtained, selected so as to give the most

accurate results. The total acreage in cotton and yearly production have been taken from the cotton exchange and other statistics, and are as reliable as can be obtained.

The yield of the crop grown in 1880 was .43 of a bale per acre, which is slightly in excess of the average yield. The temperature during this year was above the normal continuously to the 1st of June, after which it dropped below the normal and remained so the balance of the season. The rainfall was deficient up to February 1, after which it was about normal or above, except in August there was only about two-thirds of the normal, but this was both preceded and followed by an excess ranging from 50 to 100 per cent. of the normal.

The crop grown in 1881 yielded .30 of a bale per acre, which is .10 below the average. During this year the temperature averaged about 4° daily below the normal up to May 1, after which it was about 3° above the normal during the remainder of the season. The precipitation was normal or above up to March 1, after which it was generally deficient except in May, and very irregularly distributed; the amount which fell in May was decidedly in excess, and was sufficient to have washed up the crop, and was followed by a total absence of rain in June, about the normal in July, which is less than 4.00 inches, and by a marked deficiency lasting through August and September.

The largest yield per acre during the period under consideration was the crop grown in 1882; the average was .51 of a bale per acre, which is about .10 above the average. The temperature during this year was 4° to 5° daily in excess of the normal to May 1, after which it was slightly deficient to the end of the year. The precipitation was very evenly distributed throughout the year, and was generally about normal except there was a marked excess during July and August, followed by a deficiency in September.

The yield of the crop grown in 1883 was .36 of a bale per acre. The temperature during this year was very even, the deviations from the normal being slight. The precipitation was above the normal until April 1, after which it was below, and the deficiency was very marked during July, August and September.

The crop grown in 1884 averaged .31 of a bale per acre. The temperature during this year was very unevenly distributed; it was generally in excess during the winter, and about 2° daily below the normal during April, May and June, after which it

was in excess of the normal to the end of the year. The precipitation was above the normal up to and including June; the average amount which fell over the state in April was decidedly in excess, while that which fell during May averaged over 12 inches throughout the state, this delayed planting until June, which was followed by drought during July, August, and September.

The yield of the crop grown in 1885 averaged .42 of a bale per acre. The temperature during this year was generally deficient, but the departure from the normal was slight after April. The precipitation was generally about normal or above; during the first part of the year it was decidedly in excess, and during the planting and growing season the deviations from the normal were slight.

The average yield per acre for the crop grown during 1886 was .42 of a bale. The temperature during this year was generally below normal up to May, after which it averaged slightly above the normal to the end of the year. The precipitation was about normal throughout the year, except during May no rain fell, and in July the deficiency amounted to one-third of the normal.

In 1887 the crop grown yielded an average of .42 of a bale per acre. The temperature was above the normal, with the exception of the first three months, throughout the year. The precipitation was below normal up to May 1, after which it was continuously above the normal.

The yield of the crop grown in 1888 averaged .38 of a bale per acre. The temperature, with a few exceptions, was generally below the normal. The precipitation was slightly in excess of the normal except in September, no rain worthy of notice fell.

The yield of the crop grown in 1889 averaged .40 of a bale per acre. With the exception of December and January, the temperature was below the normal throughout the year. The precipitation was in excess until April 1, after which it was slightly deficient, except in June it was 2.40 inches in excess of the normal.

The crop grown in 1890 averaged .41 of a bale per acre. The temperature was generally about normal or slightly below except during December and January, when it was decidedly in excess. The precipitation was in excess until May 1, after

which it was about normal or slightly deficient, but was more generally normal to the end of the season.

In examining the years separately it is seen first, that the greatest damage has resulted from excessive rainfall in April and May, particularly in the latter month, followed by drought during June and subsequent months; and second, that the next greatest damage to cotton has resulted from drought during July and August. It is also observed that the largest yield is in years with an even or slight excess in both temperature and precipitation from May 1 to September, and while depending to some extent on the conditions which prevail previous to May 1, their effects on the crop are not so marked, yet without exception, continuous warm weather from January to May has been followed by an average yield of cotton.—*Dr. L. M. Cline in Monthly Bulletin of Texas Weather Service for April, 1891.*

BOOK NOTICES.

DR. VAN BEBBER'S TEXT-BOOK OF METEOROLOGY.*—This is the third meteorological book by officials of the German Seewarte, the other two being Dr. Sprung's Text-book, which is somewhat difficult for the untechnical reader, and Dr. van Bebber's Handbook of Practical Meteorology. The present work is intended for the less techical reader, less elementary than Mohn's excellent Elements, and of the same character as Schmid's antiquated and Kaemtz's still more antiquated books. The author is a practiced meteorologist who has made many independent studies and publications. His book covers the ground of Meteorology with some completeness and in good and condensed form. His matter is well-digested and his conclusions will generally receive the approval of meteorologists.

The work will hardly receive the adhesion outside of Germany which Schmid and Kaemtz were so fortunate as to get in their day,—especially the latter. Its point of view is too narrow. The author is not disposed to extend his field of vision beyond Europe and when he does so his statements and conclusions are often hasty and incomplete. This is especially unfortunate in a cosmopolitan science like meteorology. This lack of view is particularly noticeable in matters of American Meteorology. He

* Lehrbuch der Meteorologie für Studirende und zum Gebrauche in der Praxis von Dr. W. J. van Bebber, Abtheilungsvorstand der Deutschen Seewarte, Stuttgart, 1890, Pages XII + 391, with 120 wood cuts and 5 tables.

rarely refers to them and when he does his references are almost invariably inexact. Thus on page 166 he says that the American foehn occupies the upper Missouri valley, which is about as inexact as to say that the Iberian peninsula occupies Europe. The Chinooks extend almost to the arctic circle. Again the "Northers" (p. 168) do not extend eastward but southward. Apparently they are confounded with the more northerly "Cold-waves." On page 362, the Signal Service does not use tridaily, but bidaily observations, and has done so since July 1, 1888, and it may be very properly doubted if our Signal Service observers are "gut besoldet." The account of tornadoes, too, (p. 357) is curiously imperfect in the present state of our knowledge. It might have been written twenty years ago, and perhaps was, as it is in quotation marks, without reference to the author quoted.

THE RUSSIAN STATIONS OF THE SECOND ORDER.*—The publications of the Russian service are made according to the international scheme, and the volumes for statistics of the second order are excellent illustrations of how well this plan adapts itself to disposing of the various results from large numbers of stations. The results given are from 334 stations scattered from Saghalien and Corea to Finland and Turkey. At fifty-one of these stations temperatures of the soil were taken, limited in most cases to the surface temperatures, in some going to depths as low as 3.2 meters; at Uman, government of Kiev, the temperatures were taken at ten different depths. At forty-four stations observations were taken on the evaporation of water. Room is also found for observations of the stand of water in some of the great rivers, and for some details as to the individual stations.

METEOROLOGY AT HONG KONG.†—The observatory at Hong Kong is one of the first class, while on Victoria Peak (altitude 1,814 feet), the culmination of the island, the station is of the second class. The observations at the first include hourly observations of the principal meteorological elements and of the

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*Annalen des Physikalischen Central-Observatoriums herausgegeben von H. Wild. Director. Jahrgang, 1889, Theil II, Meteorologische Beobachtungen der Stationen 2 Ordnung in Russland nach der internationalen Schema. St. Petersburg, 1890, Quarto, 771 pages.

† Observations made at the Hong Kong Observatory in the year 1889, by W. Doberck Director. Hong Kong, 1891, Quarto, 164 pages.

magnetic elements and the tides. In addition to this there is a meteorological service for the China Sea, a time service and some other astronomical work. The staff is small and the director seems overworked.

Dr. Doberck calls attention to the station at South Cape, Formosa, as the most important in the Far East,—far surpassing the other Formosan and the Philippine stations because so much freer from the influence of mountains. This station is under the Chinese Imperial Maritime Customs Service.

A study of the rainband indications at 10 A. M. through the year showed that, when they are recorded on a scale of 0 to 5, intensities of 0 and 1, forecast absence of rain very accurately, and intensities 4 and 5 forecast as a rule very wet weather,—the latter indication being moreover frequently followed by great thunderstorms that cannot be otherwise forecast from local observations.

From 3 P. M. on May 29th to the same time on May 30th there fell at Hong Kong 22.535 inches of rain. This occurred during thunderstorms of unusually long duration and caused floods very disastrous to the colony.

CALIFORNIA METEOROLOGY.*—Such reports as Sergeant Barwick's are useful to meteorologists and instructive to the citizens of the state to which they relate. It is to be regretted that they are not published in a larger number of states. This report consists of the usual meteorological summaries (64 pages) and miscellaneous articles and notes of interest to the average reader. Some of the latter are of more general interest and for such the Signal Service Officer in charge of the Pacific Coast division has been often drawn on. A few of the others approach perilously near the confines of the territory given over to the paradoxer, and this is to be regretted because the average reader is not in a condition to discriminate between what is really valuable and what is not.

It would be of great advantage if the reports of the state services could be constructed on some uniform plan both as to matter and form. Of course the international plan is the one which should be adopted.

* Annual Meteorological Review of the State of California for the year 1890, by the Meteorological Department of the State Agricultural Society. Compiled by Sergeant James E. Barwick, Observer Signal Corps. U. S. Army, and Meteorologist to the State Board of Agriculture, Sacramento, 1891. Octavo, 118 pages, many charts.